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ABSTRACT

Two samples of students who had been extensively tested in grades 8 and 9 were followed up three years later, one sample being used to partially replicate results from the other. Data obtained included mathematics courses taken in high school, mathematics grades, retesting for knowledge of mathematics concepts, mathematical problem solving, spatial visualization, and attitudes toward mathematics. Data were used to differentiate among girls and boys taking 1-4 years of the college preparatory mathematics sequence and to predict later mathematics and spatial performance. Results are consistent with the view that sex-role factors influencing attitudes toward mathematics are most important in creating sex-related differences in mathematics performance. (Author/MK)

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Final Report

Women and Mathematics: Summary of Research from 1977-1979 NIE Grant

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Abstract

Two samples of students ($n \approx 800$) who had been extensively tested in Grade 8 and 9, were followed up three years later, one sample being used to partially replicate results from the other. Data obtained included math courses taken in high school, math grades, interview, retesting for knowledge of math concepts, mathematical problem solving, spatial visualization and attitudes toward mathematics. Data were used to differentiate (discriminant analysis) among girls and boys taking 1-4 years of the college preparatory math sequence and to predict (multiple regression) later math and spatial performance. Results are consistent with the view that sex-role factors influencing attitudes toward mathematics are most important in creating sex-related differences in mathematics performance. Conflict between female role and achievement was readily apparent in interviews. The extent to which girls saw math as a male domain in Grade 8 related to their Confidence in Learning Math in Grade 11 and to their math performance. Compared to boys, from Grade 8-11 girls' attitudes toward math became less favorable and while in Grade 8 the sexes were similar in math performance, boys were superior in Grade 11 in math performance (but not spatial performance). Confidence in Learning Mathematics was confirmed as an important variable for both sexes, but perceived Usefulness of Math and spatial visualization were more important for girls than boys. Teacher's attitude was also important for girls.

Women and Mathematics: Summary of Research

from 1977-1979 NIE Grant

Julia Sherman

The puzzle that originally intrigued me was why females should score lower than males on spatial tasks, a problem I examined in an article in 1967.[1] At that time the evidence appeared to indicate that females are verbally accelerated compared to males. The most likely explanation for that apparent fact, which is now in dispute (Maccoby & Jacklin, 1974), appeared to be some slight biological factor (more rapid maturation?) that "bent the twig" toward female reliance on verbal modes of interacting with the environment. It was hypothesized that the biologic bent was increased by sex-role[2] expectations which, in our culture and in many other cultures, do not include as many tasks which develop spatial skills for females as for males. Further, since the educational system was originally designed to accommodate males, it was designed to educate, "bring out", the weaker skill in males, namely verbal skill. This educational system, however, further emphasized verbal skills in females while simultaneously failing to develop their less sex-preferred skill, since educational curricula have given little attention to developing spatial skills (Sherman, 1971).[3] Regarding mathematics specifically, the oft-noted "sex difference" in mathematics performance was accounted for by the "sex difference" in spatial skill. Results from the last two years of research suggest that while spatial visualization has a role in contributing to sex-related differences in mathematics performance, attitudinal factors related to sex role are more important.[4]

My research in the specific area of women and mathematics began in 1973 with identification of variables that could be relevant to the development of a sex-related difference in mathematics performance. The cognitive factors included spatial visualization and vocabulary, as a measure of verbal skill and as the best single index of general intelligence.[5] Other, attitudinal factors, were identified from a review of the literature. Each of these factors was defined and a highly reliable 12 item, 5-point Likert scale was devised to measure it (see Fennema & Sherman, 1976).[6] The scales are named and major findings 1974-1976 are described in the discussion which follows. Math as a Male Domain measured the extent to which math was seen as a male domain rather than as sex-neutral (high score). From cross-sectional samples Grades 6-12, females always scored much higher on this scale (Fennema & Sherman, 1978). Males always scored higher than females on the Confidence in Learning Math Scale, the difference becoming statistically significant in Grade 8. This scale correlated -.89 with the Math Anxiety Scale so the latter was not also used in the main data gathering. The Father Scale, measuring perceived attitude toward the student as a learner of mathematics, was usually higher than the parallel Mother Scale. This indicated that students saw their fathers as more positive toward them as learners of mathematics than their mothers. In high school, boys tended to have higher scores than girls on the Mother, Father, Teacher, and perceived Usefulness of Math Scales. There was little difference between the sexes on the Attitude toward Success in Math ("fear of success") and the Effectance Motivation in Mathematics Scales. The latter measured a kind of joy in problem solving. All factors except Math as a Male Domain differentiated among groups

planning to take another year of math and those who were not (Sherman & Fennema, 1977). Both verbal and spatial skill correlated moderately with math performance measures as did Confidence in Learning Math. The other variables correlated with math performance to a lesser but significant extent.

In Grades 6-8 the sexes performed very similarly on the cognitive measures (Fennema & Sherman, 1978). In the high school years significant differences between the sexes in math performance occurred at the 2 of 4 schools which also showed the most differences between the sexes in attitudes toward mathematics. Significant differences in spatial visualization were found at 2 of the 4 schools (Fennema & Sherman, 1977), only one of which also showed a sex-related difference in mathematics performance.

Even when statistically significant, the size of the differences between the sexes was very small and it became apparent that some reports of cognitive sex-related differences had exaggerated their extent by failing to control, for example, such an obvious factor as mathematics background. (See Sherman, 1978 for further discussion of this and related points.) While some biological explanations for the sex-related difference in math performance had been suggested, close examination showed them to be lacking in empirical support (Sherman, 1977,1978). Socio-cultural explanations appeared salient, but aspects of sex-role influence remained elusive, and what role did spatial visualization play; how important was it compared to socio-cultural factors? Waber (1977) had found a relationship between rate of physical maturation and level of spatial skill. Late maturers, who are more often male than females, had higher skill. Petersen (1976)

had not found such a relationship. Was it a reliable finding? Was sex-role-linked spatial experience responsible for the difference? During 1977-1979 data were collected on these and other points, the research plans changing somewhat as new data, their implications and possibilities became evident.

Research Rationale and Procedure

The main research strategy was to do a three year Grade 9-12, 8-11 follow up of students tested in 1975 and 1976 to see how they had developed educationally and to compare the sexes. Earlier data were used to see which factors differentiated students who took more or less courses in the college preparatory mathematics sequence (1) algebra, 2) geometry, 3) algebra-trig or precalculus, 4) advanced algebra, calculus, advanced math).[7] Earlier data were also used to predict later math grades, knowledge of math concepts, mathematical problem solving skill and spatial visualization. In addition, girls were interviewed in order to gain a greater understanding of the factors differentiating girls continuing and not continuing in mathematics. Research for the second year partially replicated the first year's research. It would, of course, be impossible to present all this research within the limits of a book chapter. Instead, the reader is referred to Table 1 which provides a listing of the papers developed from the research. These present the data in more detail. This chapter will provide illustrative results and an integrated summary of the research. All studies predicting from Grade 9 and from Grade 8 used subjects from the pools described in Fennema and Sherman (1977, 1978), respectively. The variables used in the Grade 9-12 and Grade 8-11 follow-ups are described in Table 2. (Note that subjects in

analyses Grade 9-12 overlap, but are independent from subjects in analyses Grade 8-11 which overlap).

Place Tables 1 and 2 about here

Because of new laws and regulations governing participation of subjects in research, the follow-up data were not easy to obtain. Informed consent had to be obtained from parents and sometimes also from students at each major step of the study. To help increase participation and reduce bias in subject volunteering, students were paid $4-5 each for studies that required testing or interview. With a minor exception, final samples were not significantly different from the original samples (except for matched interview samples which were especially selected). All subjects were from the middle schools and high schools of the same mid-western city. Nearly all subjects were white; socio-economic status ranged from lower to upper middle class. Comparison of test scores with national norms suggested that the population was above average (see Sherman, in press-g). All subjects were tested and interviewed in their own schools using standard test instructions (with minor exceptions). Greater detail of procedures is in the individual papers; some greater detail of procedures will be presented with the results.

Factors Differentiating Math Enrollment Behavior: Results and Discussion

Discriminant Analyses Predicting Math Enrollment

For the sample used in this study (Sherman, in press-a) there was

no difference between the sexes in the cognitive measures in the 9th grade, but 42% of the girls compared to 27% of the boys took the college preparatory math sequence only through geometry. The means and standard deviations for all scores for the enrollment groups are presented in Table 3 and the standardized discriminant weights of the dependent variables are in Table 4 (listed under Study 1). For both sexes, one statistically significant discriminant function was found accounting for 91% and 72% of the variance for girls and boys respectively. For girls, the standardized weights of the discriminant function were highest for spatial visualization, vocabulary, perceived Usefulness of Math and Confidence in Learning Math; for boys, Confidence in Learning Math, math achievement, stereotyping Math as a Male Domain (weighted negatively) and Effectance Motivation in Math were highest in discriminating those who had elected 2, 3, or 4 years of college preparatory math.[8]

Place Tables 3 and 4 about here

In the following year (1979) students who had been in Grade 8 when first tested were now in Grade 11 and a partial replication of the preceding study was performed with these data (Sherman, in press-b). The variables were the same though the vocabulary and mathematics tests were different and a simplified version of the Fennema-Sherman scales (correlated about .90 with originals) was used. There were also other

differences between the studies. Subjects in the second study were in 8th grade, not 9th, when originally tested and in 11th grade, not 12th, when followed up, and the discriminant analyses were used to differentiate among students who took 1, 2, 3, or 4 years of the college preparatory mathematics sequence (not 2, 3, or 4 years as in the first study). Students in the second study taking a fourth year of math in Grade 11 can be regarded as accelerated and not entirely comparable to the group who had taken 4 years of math in the previous study (who were seniors by then).

While there was no known bias in selection procedures, females in Grade 8 scored significantly higher than males on the Mathematics Concepts Test. While the general view has been that males score higher than females on math tests, contrary instances are not rare (Sherman, 1978). There was no significant difference between the sexes on the other two cognitive measures (vocabulary and spatial visualization). Unlike the first study, the sexes differed very little in their math enrollment behavior, possibly as a result of new views of the importance of math for women, though differences between the sexes might yet appear in the senior year. The means and standard deviations of the variables for each math enrollment group are in Table 5 and the standardized discriminant weights are in Table 4 under the Study 2 heading.

One statistically significant discriminant function was found for both sexes, accounting for 81% and 75% of the variance for girls and boys respectively. For girls the standardized weights of the discriminant function were highest for vocabulary, Confidence in Learning Math, Attitude toward Success in Math and Effectance Motivation in Math. For boys, Confidence in Learning Math, vocabulary, perceived attitude

of Father toward one as a learner of mathematics, and math achievement had the highest weights in differentiating those who, as juniors, had enrolled in 1, 2, 3, or 4 years of the college preparatory math sequence.

Place Table 5 about here

In the first study, spatial visualization was the most important discriminator for females and the least important discriminator for males (11th). In the second study spatial visualization was only 6th (of 11) for females, but it carried a negative weight for males. The data are consistent with the hypothesis that spatial visualization, because it is a less sex-preferred skill, differentiates more among females than among males in predicting math enrollment behavior (provided, of course, that one has a relatively unselected sample). Confidence in Learning Math was verified as a very important factor in both girls' and boys' math enrollment behavior. In fact while much has been made of girls' math anxiety (the obverse of confidence), Confidence appeared to be even more important for males than for females.

Considering the results from both studies for each sex separately, the most important discriminators (with consistent direction of weights) for females were, in order: vocabulary, Confidence, spatial visualization, perceived Usefulness of Math, math achievement, and Effectance Motivation. Similarly for males the most important discriminators were: Confidence, math achievement, vocabulary and the perceived attitude of Father toward one as a learner of mathematics. (Results for variables not mentioned for each sex were either

inconsistent and/or with low weights.) Of course, the importance of vocabulary and math achievement are only as one would expect; the surprise is the salience of other variables, especially Confidence for both sexes and spatial visualization for females.

There was considerable communality for the two sexes in the findings, and programs designed to increase participation of students in mathematics need to bear in mind both the similarities and differences in results. Both sexes need to be encouraged and to have the kinds of experiences which build confidence in themselves as learners of mathemathics. Verbal skill, "general ability" and math achievement were important factors for both sexes; spatial visualization skill, however, was a more important factor for females than for males. This suggests the need to develop spatial visualization skills particularly in females. For females, another factor which needs special attention is the perceived Usefulness of Math, a variable quite accessible to influence by the school system.

Interview and Attitude Differences between Enrollment Groups

From the discriminant analyses, it was clear that cognitive factors were important determinants of girls' math enrollment behavior, but even in competition with these powerful factors, Confidence in Learning Math and perceived Usefulness of Math were important. The explicit sex-role variables, Math as a Male Domain and Attitude toward Success in Math were not consistent, important positive discriminators. Math as a Male Domain had also not differentiated girls planning to continue or not in mathematics (Sherman & Fennema, 1977). Would personally interviewing girls reveal a different story?

In order to remove the effect of intellectual factors as much as

possible, groups of girls enrolling in 2, 3, or 4 years (denoted Groups 2, 3, 4) of college preparatory math were equated as groups for verbal and spatial skill (see Sherman, in press-c)[9]. Groups 3 and 4 also happened to be equivalent in math achievement. All of the girls were judged intellectually capable of mastering 4 years of the college preparatory math sequence. In order to avoid biasing the interview results, no local publicity was given to the research project and the interviews were conducted (by me) at the schools under the neutral aegis of the Educational Development Project. Responses to a standard interview schedule were written down verbatim, dictated, typed, and the responses were coded independently by myself and an associate according to a reliable system worked out with pilot subjects.

I had expected that girls continuing to 4 years of college preparatory mathematics would have resolved sex-role issues better than the other girls and I had assumed that the math anxious girls would be grouped among those who stopped with only 1 or 2 years of the sequence. Neither supposition proved to be the case. Girls continuing in math showed somewhat more signs of sex-role strain even as early as Grade 9 and while Group 2 contained some prime examples of math avoiders, students could hit their "brick wall" (as Tobias has described the phenomenology of the math anxious student) at any point in the math sequence.

Several factors did differentiate the groups. Girls who took the least math were less ambitious and less concerned with achievement. Their parents' marriages were more likely to be disrupted and their mothers were more likely to work. They had more frequently left their immediate neighborhood to go places on their own since age 6.

In this sense they were more independent. On the other hand, girls who took 4 years of the college preparatory math sequence had more pleasant earliest memories of math and fewer negative experiences with teachers. As already mentioned, issues of conflict between sex role and achievement were somewhat more intense for them. For example, while most ambitious in career plans they were also most ambitious in the number of children they wished to have. At the same time they rejected the full-time working mother pattern and, more than any other group, they thought it was necessary for the mother to stay home with her children if they were to develop properly. They also tended to be more ambivalent about being smart and even somewhat more likely to "play dumb".

Overall, 51% of girls had been embarrassed about being smart; 17% would "play dumb" themselves, while 86% reported that the other girls played dumb. Math avoidance was judged present in 21%. Regardless of career plans, 62% rejected the full-time working-mother pattern.

Girls continuing in mathematics did have more positive attitudes toward mathematics, scoring higher in Grades 9 and 12 on the following scales: Usefulness in Math, Confidence in Learning Math, Teacher, Effectance Motivation in Math (Sherman, in press-d). From Grades 9-12, girls' Attitude toward Success in Mathematics ("fear of success") became more favorable and there was a nonsignificant tendency for them to regard math less as a male domain. Judging from interview comments, these changes were a function of greater maturity and perspective. In Grade 12, however, girls taking a 4th year of the college preparatory math sequence thought that math was more of a male domain than the other girls. (There had been a tendency in this direction in Grade 9.)

Putting the results from the attitude scales and interviews together, I concluded that girls continuing in mathematics were more at risk for sex-role strain than other girls and continued in mathematics in spite of this, probably because of more favorable attitudes toward mathematics and more favored, supportive circumstances.

In the following year the same procedures (with minor exceptions) were followed to interview junior girls equated on Grade 8 cognitive variables, who had enrolled in either 2 or 3 years of the college preparatory math sequence. Because these girls were not yet seniors and could elect further mathematics courses, the groups proved to be insufficiently different to demonstrate many differences between them (Sherman, in press-e). However, results confirmed those of the previous year in several ways: "fear of success" in math became less Grade 8-11; girls continuing in math had more positive attitudes toward math, came from more favored environments, were closer to parents and more influenced by them. Most girls planned to combine work, marriage and children, but plans were poorly articulated in relationship to each other; 29% would play dumb while 74% said the other girls played dumb.[10]

Data from the interviews indicate that conflict between the female sex role and achievement are still very much with us and permeate every aspect of a girl's interaction with her environment currently and in her orientation to the future. Girls continuing in math had not resolved these issues better than other girls, but instead were more at risk for sex-role strain. The discrepancy between the percentage of girls who admitted they would play dumb and the percentage who said <u>other</u> girls play dumb suggests that girls are not aware of the extent to which they adjust their behavior to conform to sex-role expectations.

Predicting Math Performance (Primarily Grades):

Results and Discussion

Test scores from Grade 9 were used to predict grades in math courses of the college preparatory math sequence in Grades 10, 11, and 12. Scores were also used to predict mathematical problem solving in Grade 12 (Stafford, 1965). Ns, means and standard deviations are given in Table 6. The raw score correlations are in Table 7 and the standardized regression coefficients and multiple correlations are in Table 8. In addition to vocabulary and math achievement which are well established as relevant to math performance, spatial visualization and affective factors especially Confidence in Learning Math related to math performance. At Grade 10, there was an overall significant difference between the sexes in regression coefficients, $F(10, \infty) = 1.88$, $p < .05$. Among other variables, spatial visualization was a significantly higher predictor for females than for males. Note also that aside from math achievement, spatial visualization was the only other significant predictor of mathematical problem solving in Grade 12.

Place Tables 6, 7, & 8 about here

In the following year a partial replication of the previous study was done in that Grade 8 test scores were used to predict grades in math courses of the college preparatory math sequence in grades 9, 10, and 11 (i.e. algebra, geometry, and algebra-trig or precalculus). The n's, means and standard deviations for each variable for all analyses are in Table 9. Raw score correlations are in Table 10 and the standardized regression coefficients and multiple correlations are in

Table 11.

In addition to math achievement, there were significant correlations between math grades and spatial visualization, Confidence in Learning Math, Teacher Scale and vocabulary (as well as other scattered findings). Vocabulary did not relate as well to math grades as one would have supposed.

Of the 9 multiple correlation coefficients, 8 were statistically significant, but as in the previous study, a large part of the variance remained unaccounted for. The only variables with consistent positive weights in predicting math grades were math achievement and to a lesser extent Confidence in Learning Math. (Neither vocabulary nor spatial visualization were significant predictors.) There were no overall differences between the sexes in regression coefficients.

Grades, of course, are only rough indices of mathematics performance. Follow-up testing seemed more likely to give useful results. Moreover, while in the previous year, a sample of girls had been given a mathematical problem solving test, no boys had been tested. Would spatial visualization also predict boys' performance as it had girls'? Would the sexes increase equally in their mathematics and spatial performance? These questions were addressed in the following study.

Place Tables 9, 10, & 11 about here

Changes Grade 8-11 in Mathematics, Spatial Visualization and Related Factors: Results and Discussion

The means and standard deviations of all variables as assessed in

Grade 8 and in Grade 11 may be found in Table 12. These data provide information on several points: factors predicting skill in mathematical problem solving and knowledge of math concepts; change in attitudes toward mathematics; factors related to skill in spatial visualization, and factors predicting confidence in oneself as a learner of mathematics.

Place Table 12 about here

Predicting Math Performance

Since different tests were used in Grades 8 and 11, it was not possible to compare the sexes directly for change in math performance. However, in Grade 8 there was no significant difference between the sexes in either mathematical problem solving or math concepts, while in Grade 11 males performed better than females, $t(208)=8.94$, $p<.01$, $t(198)=10.50$, $p<.01$, respectively. The sexes were not different in spatial visualization in Grade 8 (or 11), in the number of courses taken in the college preparatory math sequence, nor in the number of math-related course taken, yet by Grade 11 they were different in math performance.

Table 13 gives the correlations between the independent variables and scores for math concepts and problem solving in Grade 11. Correlations were similar for the two measures of math performance. Large, significant correlations were found between vocabulary, spatial visualization, years of math, math concepts and problem solving as measured in Grade 8, and math performance in Grade 11. For both sexes, Confidence in Learning Math was moderately correlated with mathematics performance. For girls, nearly every correlation between attitudes and

math performance was statistically significant; 15 of 16 correlations were $\geq .20$, but this was not the case for boys (3 of 16 correlations significant and $\geq .20$). Differences between the sexes in the correlations were significant only for the correlations between Math as a Male Domain and both measures of math performance, $p < .01$, and for the Mother Scale and Math Concepts, $p < .05$. In each case, females showed a higher, more positive correlation than males between attitudes and math performance.

Place Table 13 about here

Table 14 gives the multiple correlations and standardized regression coefficients predicting knowledge of math concepts and problem solving. All multiple correlations are large and statistically significant, accounting for 60% of the variance or more. In each case the regressions for males and females were significantly different, $F(15,164)=2.23$, $p < .01$, $F(15,180)=2.21$, $p < .01$, respectively.

Knowledge of math concepts in Grade 11 was best predicted by knowledge of math concepts in Grade 8 and number of years of college preparatory mathematics. Confidence in Learning Mathematics was a significant predictor for both sexes combined and for males, but not for females, Spatial visualization was the 4th most important predictor for both sexes combined, 3rd for females, but it was not a significant predictor for males, 11th of 14. While there was an overall difference between the sexes in the regressions, no comparison of individual regression coefficients was statistically significant.

In predicting problem solving in Grade 11, problem solving as measured in Grade 8 had the highest standardized regression coefficient

for both sexes; second was spatial visualization. Spatial visualization was a stronger predictor for females than for males, $p < .05$. Math Concepts, number of years of the college preparatory math sequence and years of math-related courses[11] also significantly predicted Grade 11 problem solving scores. Math as a Male Domain was a significant predictor for girls but not for boys. (Difference between the sexes was significant, $p < .05$.) The less a girl stereotyped math as a male domain in Grade 8, the higher her problem solving score in Grade 11. A significant predictor for males was their Grade 8 Attitude toward Success in Mathematics; it was a more positive predictor for males than for females, $p < .01$. (Aside from those mentioned there were no other differences between the sexes in standardized regression coefficients.)

Place Table 14 about here

Change in Attitudes toward Mathematics

Split-half reliabilities and stability coefficients for the Fennema-Sherman Mathematics Attiudes Scales II may be found in Table 15. Reliabilities were adequate, but somewhat low for Math as a Male Domain. Stability coefficients, Grade 8-11, were moderate to low showing considerable shifting in attitudes toward mathematics from Grade 8 to 11. The most stable attitudes for both sexes combined were Confidence in Learning Math and Effectance Motivation in Math; the least stable attitudes were Attitude toward Success in Math and perceived Usefulness of Math.

Place Table 15 about here

The results of a MANOVA analyzing changes in mean scores from Grade 8-11 showed no overall effects for sex or grade, $F(1,208)=.01$, $p>.05$, $F(1,208)=.10$, $p>.05$, respectively, but significant interactions were found for all variables, including a significant triple interaction of sex by grade by scales, $F(7,208)=2.80$, $p<.01$. This interaction showed that from Grade 8-11 attitudes toward mathematics changed differently for males and females, and differently depending upon the attitude. For this reason, to understand the results, analysis of simple effects was required. The sex-related effects were different at each grade. In the eighth grade the only significant difference between the sexes in attitudes toward mathematics was that males regarded math as more of a male domain, $F(1,208)=44.44$, $p<.01$. However, by the 11th grade, males were significantly more confident of themselves as learners of mathematics, $F(1,208)=8.73$, $p<.01$, regarded math as more useful, $F(1,208)=4.15$, $p<.05$, continued to regard math as more of a male domain, $F(1,208)=31.46$, $p<.01$.

Overall, statistically significant changes Grade 8-11 were found for these effects: girls' attitudes declined for 4 scales and improved for 2 scales; boys' attitudes declined for 1 scale and improved for 2 scales. From Grade 8-11, both girls and boys became less confident of themselves as learners of mathematics, $F(1,134)=61.17$, $p<.01$, $F(1,74)=14.25$, $p<.01$, respectively. Although girls became even less confident than boys the interaction effect was not significantly significant. Girls became less "fearful" of success in mathematics,

$F(1,134)=16.31$, $p<.01$, and perceived their mothers as more positive toward them as learners of mathematics, $F(1,134)=4.08$, $p<.05$. Males also perceived their mothers as more positive toward them as learners of mathematics, $F(1,74)=23.93$, $p<.01$, and their positive attitude increased more than the girls as shown in a significant interaction effect, $F(1,208)=3.93$, $p<.05$. Boys' perception of their fathers' attitudes toward them as learners of mathematics also improved, $F(1,74)=7.42$, $p<.01$, but this was not the case for girls. For the Teacher, Usefulness and Effectance Motivation Scales, girls' attitudes declined, $F(1,134)=6.34$, $p<.01$, $F(1,134)=5.42$, $p<.05$, $F(1,134)=7.82$, $p<.01$, while boys' attitudes improved slightly; all three interactions of sex with attitude change were statistically significant, $F(1,208)=6.61$, $p<.01$, $F(1,208)=6.93$, $p<.01$, $F(1,208)=9.52$, $p<.01$, respectively. (Simple effects not mentioned may be assumed nonsignificant.)

Predicting Spatial Visualization, Grade 11

While boys scored higher in spatial visualization than girls both in Grade 8 and in Grade 11, a repeated measures ANOVA showed no significant difference between the sexes, $F(1,208)=2.17$, $p>.05$ and no significantly greater increase in male than female spatial skill from Grade 8-11, $F(1,208)=.31$, $p>.05$. (The grade effect was, of course, significant, $F(1,208)=348.88$, $p<.01$).

Correlations between independent variables and spatial visualization in Grade 11 are in Table 16 while the standardized regression coefficients are in Table 17. Spatial visualization scores in Grades 8 and 11 were highly correlated. The correlation between the Spatial Experience Questionnaire[12] and spatial visualization in Grade 11 was

statistically significant for girls, but not for boys. The difference between the sexes in the size of this correlation (or others) was not significant.

Multiple correlations predicting spatial visualization in Grade 11 were large and statistically significant, accounting for about 60% of the variance. There was no difference between the sexes in regressions, $F(4,202)=.31$, $p>.05$. Spatial visualization as measured in Grade 8 was by far the best predictor. In the model that did not include sex as a predictor variable, for both sexes combined, the Spatial Experience Questionnaire and age of greatest growth were statistically significant predictors and Spatial Experience was a significant predictor for females. In the model including sex as a predictor, Spatial Experience remained significant, but age of greatest growth did not, nor was sex statistically significant as a predictor.

Place Tables 16 and 17 about here

Predicting Grade 11 Confidence in Learning Math

Correlations between independent variables as assessed in Grade 8 and Confidence in Learning Math in Grade 11 may be found in Table 18. There were no statistically significant differences between the sexes in the size of the correlations. Confidence in Grade 8 correlated highest with confidence in Grade 11, followed by Effectance Motivation in Math, the two measures of math performance and spatial visualization. Math as a Male Domain was a significant correlate (.27) for females but not for males. The more girls saw math as a sex-neutral rather than a male subject, the higher their confidence in learning math in Grade 11.

The multiple correlation coefficients and standardized regression coefficients predicting Confidence in Learning Math may be found in Table 19. The multiple correlations were statistically significant accounting for 40-50% of the variance. Overall, the regressions were significantly different for the two sexes, $F(13,184)=2.01$, $p<.05$. For females, vocabulary had the highest weight, a negative one, followed by positive weights for Confidence in Learning Math, Effectance Motivation, spatial visualization, and Math as a Male Domain. For males the only significant predictor was Confidence in Learning Math. Vocabulary was a more negative and Math as a Male Domain a more positive predictor for girls than for boys, both $p<.01$. There were no other statistically significant differences between the individual standardized regression coefficients.

Place Tables 18 and 19 about here

While girls and boys were not different in math performance in Grade 8, significant differences were found in Grade 11 even though there were no significant differences between the sexes on several cognitive measures in Grade 8, no significant difference in number of courses taken in the college preparatory math sequence or in math-related courses. Similar sex-related differences in math achievement in Grade 11 had previously been found at some of the high schools sampled, but not others (Fennema & Sherman, 1977). Since the presence or absence of a sex-related difference co-varied with the presence or absence of more favorable attitudes toward mathematics among males, it was concluded that the source of the difference could be attributed to sex-related

differences in these attitudinal factors. Present data are consistent with that conclusion.

While boys increased slightly more than girls in spatial skill, this difference was not statistically significant. The factors which did change differentially for the two sexes were their attitudes toward mathematics. Girls showed more and deeper declines, fewer and less extensive improvements in attitudes toward mathematics. Girls' attitudes declined for Confidence in Learning Math (as did boys'), perceived attitude of Teacher toward one as a learner of mathematics, perceived Usefulness of Mathematics and Effectance Motivation in Math.

Further evidence for the importance of sex-role factors may be found in the results of the Math as a Male Domain Scale. The extent to which math was considered sex-neutral rather than a male domain related more to female than to male math performance. For females, Math as a Male Domain was the only eighth grade affective variable with a significant weight in predicting math performance (problem solving) in Grade 11.[13] Math as a Male Domain was also a significantly more positive predictor of Confidence in Learning Math in Grade 11 for females than for males. The most likely interpretation of these findings is that the stereotyping of math as a male domain adversely affects girls' mathematics learning.

Girls' more positive attitude toward success in mathematics from Grade 8 to 11 is consistent both with data from a cross-sectional sample and from the independent longitudinal sample previously discussed (Fennema & Sherman, 1978; Sherman, in press-d) and appears to be a function of increased maturity (Sherman, in press-c,e). "Fear of success" in mathematics is but one factor in a system of sex-role

influences, and for mathematics it is less important than some of the other attitudes.

Replicating results of other data sets (Sherman, 1979; correlations only, in Sherman, in press-f), spatial visualization was a significant predictor of mathematics performance and tended to be a significantly higher predictor for girls than for boys. The correlations were not so different as the standardized regression coefficients. In competition with other variables, spatial visualization contributed more uniquely to the prediction of math performance for females than males. This is probably because of the slight male advantage in spatial visualization.[14] Spatial visualization skill is thus less likely to be problematic for males than females. Hence spatial visualization skill would differentiate more among females than males in predicting math performance.

Both the experiential factor, Spatial Experience Questionnaire, and the physiological factor, age of greatest growth, were small but statistically significant predictors of Grade 11 spatial visualization, but sex designation was not a significant predictor. This suggests that both experiential factors (Sherman, 1967) and rate of maturation (Waber, 1977), but not sex per se, could be explanations for the small male advantage in spatial visualization (i.e. since more females mature early than males). Some cautions regarding these findings are in order. A prepuberty measure of spatial visualization might well assess more accurately the full scope of the effect of rate of physical maturation and measures of spatial experience and rate of maturation were very rough. The universe of experiences that develop spatial skill is at present poorly defined and understood. The Spatial Experience Questionnaire was a first attempt to measure this dimension, and

since it was balanced for sex-stereotypic content it can not tell us if males have more spatial experience than females (in our culture). Likewise retrospective, self-report of age of greatest growth was a gross measure of rate of maturation. Further research is needed with more refined measures.

The results predicting Confidence in Learning Math in Grade 11 are particularly interesting in that females showed a significant negative weight for vocabulary and a significant positive weight for spatial visualization, while neither measure of math performance was a significant predictor. At first thought the high negative weight for vocabulary would seem anomalous, but not in view of the hypothesis that more females than males develop their verbal facility perhaps at the expense of their spatial skill (Sherman, 1967, 1978). Tobias (1978) provides an introspective account of how verbal facility interfered with mathematics learning. Effectance Motivation and Math as a Male Domain, as mentioned previously, were also significant predictors for females, but not for males. For males the only significant eighth grade predictor was Confidence in Learning Math.

Implications for Practice and Teaching and Enhancing Educational Equity

The evidence supports the view of the importance of sex-role factors in girls' math enrollment behavior and math performance. At the most general level, a consistent systems approach to educating girls must be given more careful consideration and application. Girls' educational, career and family plans are poorly articulated. The education system needs to provide girls (and boys) with more accurate and useful information about reproduction and child rearing.[15] It is not

helpful to tell girls they can be anything they want, leave them ignorant of reproduction and then put them in a class where they learn that their children will be ruined if they don't stay home to care for them personally. In addition to information in regular classes, group counseling programs and/or clubs that address the issues of coherent, workable resolutions of girls' educational, career, and family plans could pay great dividends in education as well as in reducing teenage pregnancy and improving the mental and physical health for women and children. If women (and men) are to combine child rearing and careers successfully, they need to be well educated to do both. Child-care centers for practical training could well become part of our nationwide educational network.

Within the narrower frame of girls' pursuit of mathematics, at least through high school, it is clear that girls need to be encouraged and to have positive experiences with mathematics in order to bolster their confidence. We must continue to reduce the stereotyping of mathematics as a male domain. Girls need to be better informed regarding the usefulness of mathematics and this information cannot occur later than Grade 9 and during Grade 10, as girls will begin dropping out of math classes after the 10th grade. Teachers' encouragement is crucial during this period.

The data demonstrated the importance of spatial visualization to girls' math enrollment behavior and to their math performance. Research needs to be directed toward factors affecting the development of spatial skill not only during early years, but even during the adult years. We do not assume that an illiterate adult should be written off as unteachable, nor should we assume that adults cannot improve their spatial skill. Methods of achieving this (and any improvement of spatial

skill) need to be devised, and their feasibility and advisability evaluated. We know very little about maximally developing spatial skill. What contribution do crafts, shop classes, drafting courses, sports and/or other activities make to the development of spatial skill? Contributions of biological factors, though small, still remain to be clarified. The educational system must address itself to the issue of maximally developing female intellectual competence. Among other factors, this will need to include better development of spatial visualization skill. For a swimmer with a weak kick, we provide a kick board and opportunities to develop the legs. We do not further exercise the arms. Similarly we must beware of those who wish to solve the problem by "verbalizing" math education for girls rather than to strengthen girls' visualization skills.

Changes in the educational system, such as these described, must occur in the spirit of increasing informed choices for girls and boys and not in the spirit of substituting a new, explicit coercive standard (you all must master mathematics, have a career, and not stay home with your children) for the old mostly unspoken coercive standard for girls (you must not be <u>too</u> smart, you can have a job but not a career, and you should stay home with your children).

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* If these papers are not in press by the time this article goes to press, these references will be shifted to Reference Notes.

Footnotes

[1]This summary encompasses conclusions from my research on the topic of women and mathematics begun in 1965, but concentrating on results from the NIE grant period of 1977-1979. Because of space constraints, I have cited only the most relevant literature and only literature available before September 1979 when this chapter was written. Even aspects of my own thinking not directly relevant to the 1977-1979 research are not discussed e.g. lateralization of the brain. Readers are referred to the journal articles and my books (Sherman, 1971, 1978) for more detail.

[2]In order to facilitate communication, the term sex role has been used even though I do not find it conceptually satisfactory.

[3]No inference of hostile societal motivation toward females is implied by this and it is recognized that the biologic bent may lead to or include <u>preference</u> for verbal as opposed to spatial activity among females and the obverse among males.

[4]Results (Fennema & Sherman, 1977, 1978) did not support the companion hypothesis (Sherman, 1978) that females, more than males, rely on verbal (left hemisphere) rather than spatial (right hemisphere presumably) methods in doing mathematics, <u>if</u> one expects that therefore the correlation between verbal skill and mathematics performance should be higher for females than males and the correlation between spatial visualization and mathematics performance should be

higher for males than females. This has not usually been the case; however see Connor, Serbin and Nosofsky (Note 1). Correlations are slippery creatures and increase with greater range of scores; unfortunately ranges were not reported in the 1977 and 1978 articles. Inspection of the standard deviations show that they were clearly more often larger for males than females for spatial visualization scores, but not for verbal and math measures. Thus, unless there were range differences not reflected in the standard deviations, if the hypothesis were true, correlations between verbal and math performance should have been higher for females than for males, but this was not the case. For correlations between spatial visualization and math scores, the difference between the sexes in variability should favor the hypothesis, yet the correlations for males between spatial visualization and math performance were not significantly higher than those for females. There are, however, also logical and philosophical problems about considering sex-related correlation differences as relevant evidence. Presumably what distinguishes a verbal approach from a spatial one is that the former usually involves the left hemisphere of the brain and the latter the right hemisphere of the brain. We can be fairly sure that the left hemisphere performed the verbal tasks for nearly all subjects, but we can not be so sure that the right hemisphere performed the spatial task. Furthermore correlating static achievement levels is by no means the same as in vivo knowledge of what mental processes are taking place. It is likely that definitive testing of the hypothesis will have to

await more accurate methods of EEG research.

[5]While it might seem that mathematical "ability" would be a relevant measure, there are serious conceptual difficulties in defining "mathematical ability" and in differentiating it from measures of mathematics achievement (Green, 1974). While one can be skeptical of inherent abilities, the case even for a separate mathematical ability has been unconvincing. For these reasons "mathematical ability" was not regarded as a relevant variable to the development of sex-related differences in mathematics performance.

[6]Because the intent of the research was to elucidate sex-related differences in math performance, items for the scales were devised and selected which seemed likely to tap into relevant areas, i.e. the perceived attitude of the teacher toward the student as a learner of mathematics was measured rather than, for example, the perceived skill of the teacher. One of several criteria for item selection was that the item differentiated between the sexes. The research strategy was to attempt to identify relevant variables in order to demonstrate the effect if one existed.

[7]On the advice of a math educator, the term "theoretical math" was used to describe these courses, but the term was not widely understood so the description "college preparatory math sequence" was later substituted.

[8]In this instance the more boys saw math as a male domain rather than sex-neutral, the more likely they were to continue in mathematics.

It should be noted, however, that the raw score correlations between Math as a Male Domain and math achievement were usually positive. Full discussion of male sex-role influences in learning math is unfortunately beyond the scope of the chapter.

[9]Group 2 also had 5 girls who had taken only one year of college preparatory math (algebra).

[10]During the first year girls continuing in math stereotyped math as more of a male domain than the other girls. This was not true of the partial replication. It is not clear whether the difference was due to differences in the samples, in the scales, or some other factor.

[11]Math-related courses included all math courses not part of the college preparatory math sequence and science courses requiring math as a prerequisite. Note the number of math related courses did not knowledge of math concepts, but did relate to relate to skill in mathematical problem solving for girls and for both sexes combined.

[12]The Spatial Experience Questionnaire (McDaniel, Guay, Ball, & Kolloff, Note 2) measured extent of participation in experiences that might be relevant to the development of spatial skill. Subjects recorded the frequency of their participation in 25 activities (e.g. checkers, using hand tools, tennis) on a 4-point scale. Activities selected had been rated by judges as stereotyped female, male, or neutral and items on the final questionnaire were balanced in this respect. For this reason the questionnaire is not relevant to measure sex-related differences in extent of spatial experience since there may actually be more such "male" than "female" activities. Cronbach's alpha for the questionnaire for females was .71 (n=135); males, .70

(n=75); both sexes, .67 (n=210). Age of greatest growth was used as the best single, simple index of rate of physical maturation (Nicolson & Hanley, 1953). It was ascertained by student self report.

[13]For boys, the significant negative weight for the Mother Scale and positive weight for Attitude toward Success in Mathematics were not consistent with previous research. Without replication, it seems wiser not to speculate about their meaning aside from noting that "fear of success" is not unique to females.

[14]It might be thought that the lack of a sex-related difference especially at Grade 11 is at variance with the literature, e.g. DAT norms. However, the size of the difference (2-3 items) was similar and, in fact, would be statistically significant with the same large numbers (12-13,000) as in the normative sample.

[15]This opinion is based in part on results not reported here in full, but even more on some unpublished pilot work and on my general observations as a trained clinician.

Table 1

Factors Differentiating Math Enrollment Behavior

Discriminant Analyses Predicting Math Enrollment

1. Girls' and boys' enrollment in theoretical math courses: A longitudinal study. (Sherman, in press-a)

   Discriminant analyses (n=331) were performed on Grade 9 test scores predicting those who elected 2, 3, or 4 years of the high school college preparatory math sequence.

2. Factors predicting girls' and boys' enrollment in high school mathematics. (Sherman, in press-b)

   Discriminant analyses (n=483) were performed on Grade 8 test scores predicting those who elected 1, 2, 3, or 4 years of the high school college preparatory math sequence.

Interview and Attitude Differences Between Enrollment Groups

3. Mathematics the critical filter: A look at some residues. (Sherman, in press-c)

   Girls (n=87) cognitively similar in Grade 9 who subsequently enrolled in more or less of the college preparatory math sequence were interviewed.

4. Continuing in mathematics: A longitudinal study of the attitudes of high school girls. (Sherman, in press-d)

   Attitudes toward mathematics (of sample interviewed) Grades 9-12 were compared.

5. Girls talk about mathematics and their future: A partial replication. (Sherman, in press-e)

   Girls (n=63) cognitively similar in Grade 8, who subsequently enrolled in 2 or 3 years of the college preparatory math sequence, were interviewed and their attitudes toward mathematics Grade 8-11 compared.

Predicting Math Performance (Primarily Grades)

6. Predicting mathematics performance in high school girls and boys. (Sherman, 1979)

   Grade 9 scores were used in multiple regression equations to predict later math grades and mathematical problem solving.

7. Predicting mathematics grades of high school girls and boys: A further study. (Sherman, in press-f)

   Grade 8 scores (n=255) were used in multiple regression equations to predict later math grades.

Changes Grade 8-11 in Mathematics

Spatial Visualization and Related Factors

8. Mathematics, spatial visualization and related factors: Changes in girls and boys, Grades 8-11. (Sherman, in press-g)

   Grade 8 scores were used in multiple regression equations to predict later knowledge of math concepts and mathematical problem solving skill. Grade 8 spatial skill, age of greatest growth, and spatial experience were used to predict later

Table 1 (Con.)

spatial visualization scores. Math attitudes Grades 8-11 were compared and Grade 11 Confidence in Learning Math predicted from Grade 8 scores.

Table 2

Variables Used 1977-1979 Studies

Grade 9-12 Follow-up

Data Collected in Grade 9

Vocabulary - Quick Word Test (Borgatta & Corsini, 1964)

Spatial Visualization - Space Relations test (Bennett, Seashore, & Wesman, 1973)

Math Achievement - Test of Academic Progress (Scannell, 1972).

Fennema-Sherman Mathematics Attitudes Scales (Fennema & Sherman, 1976)

Data Collected in Grade 12

Interim Math Enrollment Behavior

Math Grades

Mathematical Problem Solving - Mental Arithmetic Problems (Stafford, 1965)

Interview (n=87)

Fennema-Sherman Mathematics Attitudes Scales

Grade 8-11 Follow-up

Data Collected in Grade 8

Vocabulary (Thorndike & Hagen, 1971)

Spatial Visualization (Bennett et al. 1973)

Mathematics Concepts Test (Naslund & Thorpe, 1971)

Mathematical Problem Solving (Wearne, 1977)

Fennema-Sherman Mathematics Attitudes Scales II

Data Collected in Grade 11

Interim Math Enrollment Behavior

Spatial Experience Questionnaire (McDaniel, Guay, Ball, & Kolloff, Note 2)

Age of Greatest Growth

Math Grades

Mathematics Basic Concepts (Educational Testing Service, Note 3)

Mathematical Problem Solving (Stafford, 1965)

Spatial Visualization (Bennett et al. 1973)

Interview (n=63)

Fennema-Sherman Mathematics Attitudes Scales II

Table 3

Ns, Means and Standard Deviations of Females and Males for all Variables as Assessed in Grade 9 for Groups Differing in Years of Theoretical Math

	Possible Range		Algebra & Geometry		3 Years Math		4 Years Math	
			F	M	F	M	F	M
n			59	36	68	52	31	64
Math Achievement	0-48	M	20.66	21.86	23.94	24.69	29.06	28.47
		SD	6.90	6.46	6.68	7.45	7.85	6.71
Quick Word Test	0-100	M	52.97	55.56	58.51	58.96	64.94	62.53
		SD	14.63	11.01	12.09	12.20	10.92	12.58
Spatial Visualization	0-60	M	32.08	34.14	37.57	38.31	41.77	38.37
		SD	10.07	10.12	8.60	9.83	8.34	10.40
Confidence in Learning Math	12-60	M	40.07	38.56	43.57	45.21	48.52	47.44
		SD	9.28	9.32	9.03	7.59	5.32	6.88
Mother	12-60	M	41.51	45.00	45.51	46.10	46.65	47.48
		SD	7.39	4.75	6.74	5.85	8.28	6.88
Father	12-60	M	43.29	44.39	46.18	46.81	46.77	47.94
		SD	6.95	6.70	6.98	6.87	9.18	6.64
Attitude toward Success in Math	12-60	M	46.95	46.03	47.43	46.29	46.77	47.55
		SD	7.11	6.50	6.40	5.21	6.40	6.41
Teacher	12-60	M	40.07	41.31	43.41	42.98	43.26	44.72
		SD	6.57	5.58	6.75	6.35	6.09	6.65
Math as Male Domain	12-60	M	52.58	46.69	54.32	44.83	53.10	45.91
		SD	5.83	6.62	5.34	7.28	5.76	8.84
Usefulness of Mathematics	12-60	M	42.31	45.75	47.13	46.73	49.87	48.83
		SD	9.72	7.81	7.80	7.59	6.49	7.50
Effectance Motivation in Math	12-60	M	35.56	34.64	39.28	38.37	44.03	41.45
		SD	9.30	6.77	8.66	7.55	6.19	7.17

Table 4

Standardized Discriminant Weights of Dependent Variables Differentiating Math Enrollment Behavior

	Females		Males	
Dependent Variables	Study 1 Weight	Study 2 Weight	Study 1 Weight	Study 2 Weight
Spatial Visualization	.36	.15	.01	-.10
Vocabulary	.32	.48	.16	.43
Usefulness of Mathematics	.29	.14	-.02	-.05
Confidence in Learning Mathematics	.26	.25	.56	.62
Mathematics Achievement	.19	.17	.34	.33
Father	-.19	.04	.06	.37
Effectance Motivation in Math	.17	.19	.26	-.16
Attitude toward Success in Math	-.16	.21	.02	-.19
Math as a Male Domain	-.16	.10	-.28	-.11
Teacher	.12	-.09	-.08	.12
Mother	.08	-.07	.10	.00
Canonical Correlation	.56	.61	.50	.65

Table 5

Means and Standard Deviations for All Variables as Assessed in Grade 8 for Groups Differing in Years of Theoretical Math

		Algebra		Algebra & Geometry		3 Years Math		4 Years Math	
		F	M	F	M	F	M	F	M
Math Concepts[a]	M	25.57	24.17	25.57	26.53	30.99	29.34	34.67	34.53
	SD	5.16	7.48	5.78	6.39	4.85	6.13	3.18	3.72
Vocabulary	M	13.87	13.04	16.20	16.03	17.66	17.25	19.86	18.60
	SD	3.55	4.21	3.05	4.02	3.20	3.03	3.05	3.27
Spatial Visualization	M	27.09	28.21	28.36	30.87	33.58	31.72	36.86	41.20
	SD	10.49	9.56	9.78	9.66	9.05	10.55	7.87	13.17
Confidence in Learning Math	M	38.39	42.71	42.59	43.84	47.26	49.53	51.05	53.13
	SD	8.73	8.01	9.18	8.02	7.03	6.16	5.78	5.77
Mother	M	40.83	42.12	42.70	42.74	44.11	44.30	45.95	46.87
	SD	5.80	6.15	5.63	5.86	5.61	5.62	6.97	5.22
Father	M	41.26	39.33	43.87	45.39	46.05	45.58	45.52	48.13
	SD	6.21	7.57	6.74	6.69	6.80	6.33	6.69	5.24
Attitude toward Success in Math	M	45.04	45.54	44.48	46.29	46.88	47.31	48.90	46.47
	SD	5.86	6.09	5.74	4.89	5.78	6.01	5.99	4.58
Teacher	M	40.96	40.63	41.68	41.26	44.68	44.47	48.00	47.60
	SD	6.12	6.40	7.40	6.35	5.77	6.61	6.09	5.59
Math as Male Domain	M	50.78	44.33	52.77	47.47	54.42	48.81	56.19	49.60
	SD	5.62	6.57	4.42	7.31	4.60	7.13	3.09	3.74
Usefulness of Math	M	44.96	42.67	44.02	46.29	48.20	48.16	52.00	49.53
	SD	7.76	8.19	7.52	8.79	7.47	7.81	5.71	6.90
Effectance Motivation in Math	M	34.87	37.37	37.70	36.34	39.92	38.91	45.67	41.73
	SD	8.59	7.37	7.30	8.77	7.81	7.61	5.77	6.85
n		23	24	56	38	76	65	21	15

[a]Possible ranges: Math Concepts, 0-40; Vocabulary, 0-25; Spatial Visualization, 0-60; Attitude Scales, 12-60.

Table 6

Means, Standard Deviations, and ns for All Variables for All Analyses

	Possible Range		10th Grade Analysis		11th Grade Analysis		12th Grade Analysis	Problem Solving
			Female	Male	Female	Male	Female	Female
Math Achievement	0-48	M	23.75	25.76	25.80	27.21	29.03	27.06
		SD	7.61	7.36	7.46	6.99	7.98	7.19
Vocabulary	0-100	M	57.65	59.85	61.12	61.25	64.57	65.04
		SD	13.56	12.36	11.72	12.58	10.90	9.87
Spatial Visualization	0-60	M	36.38	37.47	39.06	38.43	41.83	41.02
		SD	9.80	10.23	8.47	10.36	8.48	7.81
Confidence in Learning Math	12-60	M	43.28	44.76	45.26	46.40	48.37	43.66
		SD	9.03	8.45	8.38	7.49	5.34	10.03
Mother	12-60	M	44.29	46.45	45.89	47.01	46.23	45.48
		SD	7.57	6.18	7.57	6.53	8.09	7.67
Father	12-60	M	45.27	46.68	46.53	47.90	46.47	45.72
		SD	7.55	6.90	7.81	6.49	9.18	8.12
Attitude toward Success in Math	12-60	M	47.13	46.85	47.29	46.84	46.53	47.61
		SD	6.66	6.10	6.59	5.88	6.37	6.25
Teacher	12-60	M	42.55	43.41	44.42	44.02	44.80	43.39
		SD	6.84	6.32	6.57	6.48	5.62	7.26
Math as Male Domain	12-60	M	53.47	45.68	53.74	45.31	52.87	54.47
		SD	5.63	7.91	5.78	8.20	5.71	5.12
Usefulness of Mathematics	12-60	M	45.87	47.45	48.18	48.02	49.67	46.28
		SD	8.83	7.68	7.71	7.45	6.49	8.90
Effectance Motivation in Math	12-60	M	38.85	38.77	40.71	40.27	43.90	40.48
		SD	9.00	7.70	8.29	7.38	6.25	8.26
Dependent Variables[a]		M	2.68	2.90	2.52	2.57	2.83	14.54
		SD	1.14	1.06	.96	1.06	1.05	3.96
n			157	148	85	109	30	85

[a]Scores for grades in Grades 10, 11, 12 (Possible range: 0-4) and for problem solving (Possible range: 1-25)

Table 7

Correlations between Dependent Variables and Independent Variables

	Grade in 10		Grade in 11		Grade in 12	Problem Solving
	Female	Male	Female	Male	Female	Female
Math Achievement	.58**	.30**	.21	.21*	.51**	.57**
Vocabulary	.48**	.31**	.11	.14	-.02	.27*
Spatial Visualization	.44**	.26**	.16	.09	.44*	.33**
Confidence in Learning Math	.39**	.19*	.29**	.15	.28	.34**
Mother	.26**	.07	.11	.05	.36	.24*
Father	.23**	.13	.13	.09	.10	.26*
Attitude toward Success in Math	.13	-.07	.18	.08	-.06	-.03
Teacher	.36**	.15	.20	.16	.25	.37**
Math as Male Domain	.21**	-.05	.17	.14	.12	-.02
Usefulness of Mathematics	.25**	-.08	.23*	.09	.12	.16
Effectance Motivation in Math	.29**	.09	.31**	.19*	.39*	.13
n	157	148	85	109	30	85

*$p < .05$.

**$p < .01$.

Table 8

Multiple Correlation Coefficients and Standardized Regression Coefficients Predicting Grades in 10th, 11th and 12th years and Mental Arithmetic Problems Test

Independent Variables	Grade in 10			Grade in 11			Grade in 12	Problem Solving
	Females	Males	Both	Females	Males	Both	Females	Females
Math Achievement	.26**	.11	.18**	.09	.15	.13	.35	.42**
Vocabulary	.25**	.23**	.25**	.05	.04	.04	-.17	.07
Spatial Visualization	.21**	.12	.19**	.11	.03	.05	.03	.20*
Confidence in Learning Math	.22**	.09	.15*	.18	.02	.09	.06	.07
Mother	-.06	.06	.01	-.15	-.13	-.13	.25	.13
Father	-.03	.04	-.01	-.02	.04	.04	.21	-.03
Attitude toward Success in Math	.07	-.07	.01	.08	-.01	.03	-.56*	.01
Teacher	.13	.18	.12	.00	.03	.01	.34	.21
Math as Male Domain	.00	-.09	-.06	.02	.14	.06	.11	-.16
Usefulness of Mathematics	-.01	-.25*	-.11	.05	-.06	.00	-.51	-.09
Effectance Motivation in Math	-.01	-.02	.00	.21	.16	.17	.44	-.11
Multiple Correlation Coefficient	.69**	.46**	.56**	.41	.30	.32*	.75	.65**
n	157	148	305	85	109	194	30	85

*p < .05.
**p < .01.

Table 9

Means, Standard Deviations, and ns for All Variables for All Analyses

	Possible Range		Algebra		Geometry		Algebra-Trig	
			Female	Male	Female	Male	Female	Male
Math Achievement	0-40	M	28.78	27.49	30.74	29.79	31.82	30.81
		SD	5.56	6.67	5.21	6.13	4.74	5.79
Vocabulary	0-25	M	16.59	16.22	17.69	17.26	17.98	17.61
		SD	3.45	3.86	3.24	3.41	3.43	3.04
Spatial Visualization	0-60	M	31.08	30.70	33.08	33.34	34.24	34.10
		SD	9.96	10.02	9.34	11.04	9.24	11.61
Confidence in Learning Math	12-60	M	44.25	46.67	46.39	49.11	48.07	50.46
		SD	8.72	7.47	8.00	6.69	6.91	5.99
Mother	12-60	M	42.86	43.38	43.94	44.32	44.26	44.86
		SD	5.83	5.80	5.84	5.74	5.72	5.57
Father	12-60	M	44.36	44.48	45.42	45.92	45.67	46.04
		SD	6.93	7.05	6.84	6.31	6.56	6.25
Attitude toward Success in Math	12-60	M	45.88	46.55	46.36	47.06	47.58	47.09
		SD	5.57	5.66	5.86	5.44	5.71	5.67
Teacher	12-60	M	42.73	42.59	44.26	44.10	45.33	44.92
		SD	6.74	6.60	6.59	6.72	5.84	6.58
Math as a Male Domain	12-60	M	53.16	47.72	54.21	48.80	54.83	48.77
		SD	4.71	7.06	4.46	6.72	4.18	6.58
Usefulness of Mathematics	12-60	M	46.09	46.76	47.41	47.94	48.79	48.49
		SD	7.89	8.22	7.55	8.17	7.19	7.58
Effectance Motivation in Math	12-60	M	38.25	37.44	39.96	38.66	41.38	39.42
		SD	8.07	8.02	7.84	8.24	7.47	7.58
Grades	0-4	M	2.66	2.58	2.77	2.85	2.89	2.75
		SD	1.04	1.10	1.05	.91	1.02	.93
n			140	115	140	106	84	77

Table 10

Correlations between Grades and Independent Variables

	Algebra		Geometry		Algebra-Trig	
	Female	Male	Female	Male	Female	Male
Math Achievement	.41**	.43**	.42**	.37**	.33**	.20
Vocabulary	.14	.27**	.24**	.12	.25*	.12
Spatial Visualization	.27**	.16	.28**	.27**	.23*	.27*
Confidence in Learning Math	.35**	.22*	.23**	.41**	.19	.18
Mother	.11	-.14	.03	.13	.24*	.13
Father	.11	-.09	.09	.15	.10	-.03
Attitude toward Success in Math	.07	-.13	-.07	.06	-.06	.01
Teacher	.27**	-.04	.30**	.21*	.26*	.06
Math as a Male Domain	.15	-.04	.11	.04	-.04	-.19
Usefulness of Mathematics	.17*	-.02	.15	.20*	.18	-.05
Effectance Motivation in Math	.21**	.04	.18*	.20*	.13	.07
n	140	115	140	106	84	77

*p<.05.

**p<.01.

Table 11

Multiple Correlation Coefficients and Standardized Regression Coefficients Predicting Grades in Algebra, Geometry and Algebra-Trig

Independent Variables	Algebra			Geometry			Algebra-Trig		
	Females	Males	Both	Females	Males	Both	Females	Males	Both
Math Achievement	.33**	.37**	.37**	.30**	.30**	.28**	.20	.06	.15
Vocabulary	-.10	.14	.00	.02	-.03	-.01	.11	.05	.09
Spatial Visualization	.10	-.12	-.01	.10	.00	.09	.12	.19	.14
Confidence in Learning Math	.27*	.36**	.27**	-.06	.41**	.16	.00	.16	.02
Mother	.00	-.14	-.08	-.16	-.10	-.12	.34	.22	.23*
Father	-.05	-.02	-.03	.00	.16	.06	-.08	.00	-.04
Attitude toward Success in Math	.07	-.19*	-.04	-.13	-.05	-.08	-.06	.06	-.04
Teacher	.08	-.06	.02	.36**	.02	.18*	.08	.06	.11
Math as a Male Domain	-.01	-.08	-.04	.04	-.12	-.04	-.23	-.26	-.13
Usefulness of Math	-.08	.05	-.04	-.03	.04	.00	.06	-.27	-.14
Effectance Motivation in Math	-.09	-.02	-.03	.01	-.11	-.02	-.08	-.03	.01
Multiple Correlation Coefficient	.48**	.56**	.47**	.51**	.52**	.47**	.48*	.44	.39**
n	140	115	255	140	106	246	84	77	161

*$p < .05$.
**$p < .01$

Table 12

Raw Score Means and Standard Deviations for All Variables as Assessed in Grades 8-11

Variable	Possible Range		Female Grade 8	Female Grade 11	Male Grade 8	Male Grade 11
Vocabulary	0-25	M	16.88		17.61	
		SD	3.52		3.10	
Spatial Visualization	0-60	M	31.45	39.96	33.20	42.23
		SD	9.87	9.82	10.86	9.76
Math Concepts	0-40[a] 0-50	M	29.37	37.32[b]	29.33	41.75[b]
		SD	5.80	8.07	6.23	7.94
Problem Solving	0-23[a] 0-26	M	12.36	12.10	12.36	13.97
		SD	4.15	4.01	4.68	4.93
Confidence in Learning Math	12-60	M	45.53	39.70	47.33	43.73
		SD	8.56	9.79	8.09	8.92
Math as Male Domain	12-60	M	53.82	53.93	48.55	49.40
		SD	4.81	5.28	6.55	6.14
Attitude toward Success in Math	12-60	M	46.55	48.75	46.63	47.95
		SD	5.78	5.91	6.57	7.28
Mother	12-60	M	43.88	45.16	43.60	46.81
		SD	5.94	7.80	5.74	6.23
Father	12-60	M	44.99	45.62	44.47	46.91
		SD	6.62	8.30	7.15	7.72
Teacher	12-60	M	44.09	42.50	42.73	43.80
		SD	6.65	8.16	7.08	6.81
Usefulness of Math	12-60	M	47.30	45.54	46.47	48.29
		SD	7.49	9.71	8.92	8.76
Effectance Motivation in Math	12-60	M	39.45	37.38	37.45	39.23
		SD	8.03	10.52	7.89	8.57

Table 12 (Con.)

Variable	Possible Range		Female Grade 8	Female Grade 11	Male Grade 8	Male Grade 11
Years Math	0-4	M		2.53		2.69
		SD		.97		.97
Math-Related Courses	0-9	M		1.49		1.69
		SD		1.14		1.22
Spatial Experience	0-25	M		19.89		19.88
		SD		6.18		6.34
Age Greatest Growth		M		13.46		14.41
		SD		1.23		1.25
n				135		75

[a]Range for SRA Mathematics Concepts Test (Grade 8) above, ETS Mathematics Basic Concepts (Grade 11) below; similarly range for Romberg-Wearne Problem Solving (Grade 8) above, Mental Arithmetic Problems Test (Grade 11) below.

[b]n=125, females; 69, males.

Table 13

Correlations Between Math Concepts, Mental Arithmetic Problems Test and Independent Variables

	ETS Math Basic Concepts		Mental Arithmetic Problems	
Independent Variable[a]	Female	Male	Female	Male
Vocabulary	.63**	.45**	.56**	.52**
Spatial Visualization	.54**	.50**	.53**	.62**
SRA Math Concepts	.79**	.79**	.67**	.72**
Romberg-Wearne Problem Solving	.70**	.66**	.68**	.79**
Confidence in Learning Math	.43**	.54**	.41**	.39**
Math as Male Domain	.45**	.02	.38**	-.07
Attitude toward Success in Math	.21*	.06	.17	.21
Mother	.25**	-.12	.27**	.02
Father	.30**	.07	.23**	.01
Teacher	.37**	.18	.36**	.18
Usefulness of Mathematics	.31**	.14	.32**	.16
Effectance Motivation in Math	.30**	.26*	.33**	.15
Years Math	.71**	.63**	.59**	.46**
Math-Related Courses	.05	.24*	.22**	.31**
n	125	69	135	75

[a]All test scores as assessed in Grade 8.

*$p < .05$.

**$p < .01$.

Table 14

Multiple Correlation Coefficients and Standardized Regression Coefficients Predicting ETS Math Basic Concepts and Mental Arithmetic Problems Test

	ETS Math Basic Concepts			Mental Arithmetic Problems		
Independent Variable	Female	Male	Both	Female	Male	Both
Vocabulary	.05	-.03	.07	.09	.02	.11
Spatial Visualization	.17**	.04	.12*	.26**	.16	.20**
SRA Math Concepts	.37**	.41**	.42**	.07	.24*	.19**
Romberg-Wearne Problem Solving	.10	.16	.07	.31**	.48**	.32**
Confidence in Learning Math	.12	.23*	.21**	.02	-.01	.11
Math as Male Domain	.11	-.05	-.06	.14*	-.07	-.08
Attitude toward Success in Math	.03	.06	.08	-.05	.24**	.09
Mother	.02	-.22*	-.03	.08	-.02	.07
Father	.04	.10	.07	-.04	-.02	-.06
Teacher	.01	-.16	-.11	.04	-.06	-.03
Usefulness of Mathematics	-.06	-.02	-.08	-.05	-.17	-.10
Effectance Motivation in Math	-.13	.08	-.05	-.01	-.02	-.04
Years Math	.27**	.29**	.29**	.16*	.12	.12*
Math-Related Courses	.01	.03	.03	.20**	.14	.17**
Multiple Correlation Coefficient	.87**	.88**	.85**	.80**	.87**	.81**
n	125	69	194	135	75	210

*$p < .05$.
**$p < .01$.

Table 15

Split-Half Reliabilities and Stability Coefficients,

Fennema-Sherman Mathematics Attitudes Scales II

	Split-Half Reliabilities			Stability Coefficients		
	Females	Males	Both	Females	Males	Both
Confidence in Learning Math	.90**	.87**	.89**	.56**	.53**	.56**
Math as Male Domain	.61**	.73**	.69**	.46**	.42**	.52**
Attitude toward Success in Math	.80**	.79**	.79**	.42**	.30*	.37**
Mother	.82**	.84**	.83**	.46**	.55**	.48**
Father	.86**	.80**	.84**	.52**	.46**	.49**
Teacher	.89**	.82**	.87**	.52**	.51**	.50**
Usefulness of Math	.90**	.86**	.89**	.51**	.28*	.41**
Effectance Motivation in Math	.90**	.8[illegible]**	.88**	.60**	.44**	.53**
n	137	76	213	137	76	213

*$p < .05$.

**$p < .01$.

Table 16

Correlations of Spatial Visualization in Grade 11 and Independent Variables

Independent Variable	Female	Male
Spatial Visualization[a]	.77**	.82**
Spatial Experience	.18*	.02
Age Greatest Growth	-.02	.01
n	135	75

[a]As measured in Grade 8.

*$p < .05$.

**$p < .01$.

Table 17

Multiple Correlation Coefficients and Standardized Regression Coefficients Predicting Spatial Visualization, Grade 11

Independent Variables	Females	Males	Both	Both
Spatial Visualization, Grade 8	.77**	.83**	.79**	.79**
Spatial Experience	.11*	.05	.09*	.09*
Age of Greatest Growth	.11[a]	.03	.09*	.08
Sex				.02
Multiple Correlation Coefficients	.78**	.83**	.80**	.80**

[a]The exact value was .107, $p < .06$.

*$p < .05$.

**$p < .01$.

Table 18

Correlations between Grade 11 Confidence in Learning Math and Independent Variables as Assessed in Grade 8

Independent Variable	Females	Males	Both
Vocabulary	.06	.28*	.14*
Spatial Visualization	.34**	.43**	.38**
SRA Math Concepts	.40**	.44**	.40**
Romberg-Wearne Problem Solving	.37**	.46**	.39**
Confidence in Learning Math	.56**	.53**	.56**
Math as Male Domain	.27**	.00	.06
Attitude toward Success in Math	.13	.10	.12
Mother	.21*	.21	.20**
Father	.15	.11	.13
Teacher	.47**	.41**	.42**
Usefulness of Mathematics	.36**	.28*	.31**
Effectance Motivation in Math	.57**	.36**	.46**
n	135	75	210

*$p < .05$.

**$p < .01$.

Table 19

Multiple Correlation Coefficients and Standardized Regression Coefficients Predicting Grade 8 Confidence in Learning Math from Independent Variables as Assessed in Grade 8

Independent Variable	Females	Males	Both
Vocabulary	-.31**	.08	-.12
Spatial Visualization	.22**	.04	.18**
SRA Math Concepts	.12	.05	.12
Romberg-Wearne Problem Solving	.15	.15	.09
Confidence in Learning Math	.29**	.41**	.39**
Math as Male Domain	.16*	-.25	-.13*
Attitude toward Succes in Math	-.07	-.12	-.03
Mother	-.03	.12	.02
Father	-.10	-.09	-.08
Teacher	.08	.19	.09
Usefulness of Mathematics	-.03	-.06	-.06
Effectance Motivation in Math	.24*	.11	.17*
Multiple Correlation Coefficient	.70**	.67**	.66**
n	135	75	210

*$p < .05$.

**$p < .01$.